PollnSAR and Multi-frequency Image Acquisition with the F-SAR Airborne SAR Instrument

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Outline

- The F-SAR sensor concept & hardware
- X-Band PolSAR & single-pass PolinSAR
- Multi-frequency data acquisition
- Summary
E-SAR and F-SAR – Versatile Tools for Airborne Active Microwave Remote Sensing

• The E-SAR has been operated and improved since 1984 by the Microwaves and Radar Institute in cooperation with DLR’s Flight Facilities
• Few years ago the development of a much improved successor, the F-SAR was initiated
• Since 2012, F-SAR is (mostly) completed and fully replaces the E-SAR
The advanced airborne sensor F-SAR

New features (compared to E-SAR):
- significantly enhanced resolution and image quality
- simultaneous data recording in up to four frequency bands
- modular design for easy reconfiguration
- single-pass polarimetric interferometry in X- and S-band
- fully polarimetric capability in all frequencies

<table>
<thead>
<tr>
<th>E-SAR technical characteristics</th>
<th>F-SAR technical characteristics</th>
</tr>
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<tbody>
<tr>
<td><strong>RF [GHz]</strong></td>
<td>9.6 5.3 1.3 0.35</td>
</tr>
<tr>
<td><strong>BW [MHz]</strong></td>
<td>50-100 (selectable)</td>
</tr>
<tr>
<td><strong>PRF [kHz]</strong></td>
<td>up to 2</td>
</tr>
<tr>
<td><strong>Rg res. [m]</strong></td>
<td>1.5 1.5 2.0 3.0</td>
</tr>
<tr>
<td><strong>Az res. [m]</strong></td>
<td>0.2 0.3 0.4 1.5</td>
</tr>
<tr>
<td><strong>Pol/InSAR</strong></td>
<td>+/- +/- +/o +/-</td>
</tr>
<tr>
<td><strong>Rg cov [km]</strong></td>
<td>3-5</td>
</tr>
<tr>
<td><strong>Sampling</strong></td>
<td>6-8 Bit complex; 100MHz; max number of samples 4 K per range line; 1 recording channel.</td>
</tr>
</tbody>
</table>
DLR’s New F-SAR Sensor

F-SAR core modules
X-band rack
C/S-band rack
L-band rack
P-band rack

modular cabin layout

F-SAR system layout
High-Resolution Polarimetric Imaging

- **X-band**: 0.25m resolution
- **C-band**: 0.65m resolution
- **S-band**: 0.65m resolution
- **L-band**: 1.0m resolution
High-Resolution Polarimetric Imaging

Mean Noise Equivalent $\sigma_0$ over Off-Nadir Angle

\[ \text{NESZ} = \frac{I}{\gamma_{hv/vh}} - I \]
Interferometer:

- 1.6m mechanical baseline
- Full- and half-baseline modes ($2\pi$ ambiguity ≈ 20 / 40m)
- Fully polarimetric acquisition on both antennas

Limits:

- In quadpol XTI modes only half range resolution (no step-frequency)
- No quadpol simultaneous full- / half-baseline acquisitions

Experimental results:

- Kaufbeuren, DLR’s airborne calibration site
- Island Juist, German Wadden Sea
- Traunstein, forest test site
X-Band Polarimetry: Juist Island / Wadden Sea
X-Band Polarimetry: Juist Island / Wadden Sea

- Amplitude
- Entropy
- Mean alpha
X-Band Single-Pass PolInSAR: Juist Island / Wadden Sea
X-Band Single-Pass PolInSAR: Juist Island / Wadden Sea

amplitude

coherence

phase (HH)
Single-Pass PolInSAR: Kaufbeuren

- PolSAR amplitude
- PolInSAR coherence
- Amplitude / phase (HH, DEM corrected)
X-Band Single- / Repeat-Pass Comparison

- Amplitude / phase (HH)
- Coherence, quadpol SP
- Coherence, HH, RP 15m
Multispectral polarimetric SAR: Current Options

- **Sensor hardware**
  - All F-SAR subsystems are now completed (X-, C-, S-, L- and P-band)
  - Digital back-end features 2 + 2 receive channels
  - Potential for up to 4 simultaneous quadpol acquisitions

- **Current limits**
  - Disc array 2 not yet implemented in (certified) flight configuration
  - Receive channel switch for L- and P-band not yet programmed
  - Combination of XCSL- and P-band antennas not yet certified
  - Currently possible modes: XC & XS quadpol, XCL & XSL singlepol

- **Ongoing works**
  - Implementation of 4-channel recording via onboard-processor
  - First multispectral PolSAR recordings expected in 2013
Multispectral polarimetric SAR: Simultaneous X/S-band

X-band quadpol
65cm resolution

S-band quadpol
65cm resolution
Only few observable differences between X- and S-band 😞

But: data acquired in late November, mostly unvegetated surfaces

More trials with more bands to come…
Summary

- **Single-Pass PolInSAR**
  - F-SAR’s X-Band polarimetric interferometer is performing well
  - Polarimetry can be strong even at X-band!
  - Unexpected volume(?) decorrelation at X-band, 2 layers? Dedicated experiment needed!
  - Next-step: S-band single-pass PolInSAR (and XS-PolInSAR!)

- **Multispectral SAR**
  - F-SAR still limited, but multispectral SAR data acquisitions are on the way
  - X/S-band comparisons without dramatic backscattering differences…
  - More data needed, especially from summer acquisitions
  - More simultaneous bands will be available soon
Free F-SAR Demo Data

POLINSAR‘13 Special Edition

- X-band fully polarimetric (25x25cm resolution)
- S-band fully polarimetric (50x65cm resolution)

Access:
⇒ pass by with a memory stick! ⇐
Questions ?
High-Resolution Polarimetric Imaging

Kaufbeuren, Germany
F-SAR X-band quadpol, (VV, HV, HH)
0.25m resolution (760MHz)
High-Resolution Polarimetric Imaging

Wallerfing, Germany
F-SAR C-band quadpol, (VV, HV, HH)
0.65m resolution (300MHz)
High-Resolution Polarimetric Imaging

Oensingen (Switzerland)
F-SAR, S-Band quadpol (HH, HV, VV)
0.5m x 0.65m resolution, 5 looks
High-Resolution Polarimetric Imaging

Forest near Düren (Germany)
F-SAR, L-Band quadpol (HH, HV, VV)
1.0m resolution (150MHz)
P-Band Interferometry (repeat-pass)

InSAR phase (VV)

PolInSAR coherence

baseline: ~10m, ~20min
F-SAR: Noise Equivalent Sigma Zero

NESZ estimation via HV/VH cross-correlation:

\[ \text{NESZ} = \frac{I}{\gamma_{hv/vh}} - I \]
F-SAR: Polarimetric Accuracy (Phase / Crosstalk)

HH/VV phase imbalance

- X-band: \( \mu = -0.1 \text{deg} \), \( \sigma = 1.8 \text{deg} \)
- S-band: \( \mu = -0.8 \text{deg} \), \( \sigma = 4.0 \text{deg} \)
- L-band: \( \mu = 1.5 \text{deg} \), \( \sigma = 7.1 \text{deg} \)

Polarimetric cross-talk

- X-band: \(-35.1 \text{dB} \) (-29.5 dB)
- S-band: \(-39.8 \text{dB} \) (-31.2 dB)
- L-band: \(-42.4 \text{dB} \) (-33.7 dB)